

Validation of the operational IASI L2 processor using AIRS and ECMWF data: clear and cloudy retrievals

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Introduction

Purpose

Test SOME ASPECTS of the IASI Level 2 Product Processing Facility (IASI L2 PPF) specifications with real space based AIRS data in order to:

- Gain experience with real space based data retrievals
- Validate single components of the IASI L2 PPF
- Select the best possible algorithms and parameters implemented in the IASI L2 PPF

Available algorithms in the IASI L2 PPF

The IASI L2 PPF has the following retrieval algorithms:

- Statistical retrievals:
 - Artificial Neural Networks (ANN)
 - Empirical Orthogonal Functions (EOF)
- Iterative or variational retrieval:
 - Levenberg-Marquardt minimisation method using a fast radiative transfer model

CLEAR SKY over OCEAN retrievals

CLEAR SKY algorithms and scenarios tested with real AIRS data

- EOF and variational retrievals tested
- Tested for day and night cases
- Tested for clear sky over ocean scenarios. A very tight cloud detection algorithm was used (see Appendix A).
- Tested for latitudes equatorwards of 50° and scan angles smaller than 15°
- Temperature, water vapour profiles and SST were retrieved. No surface emissivity, ozone or trace gases were retrieved.

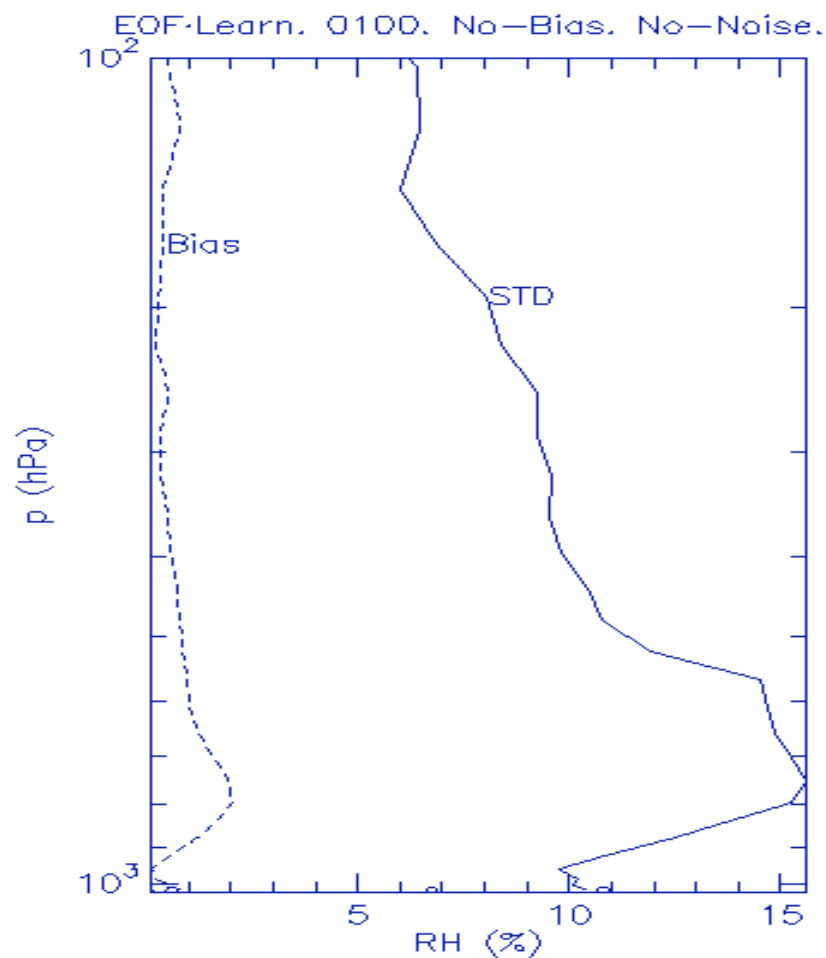
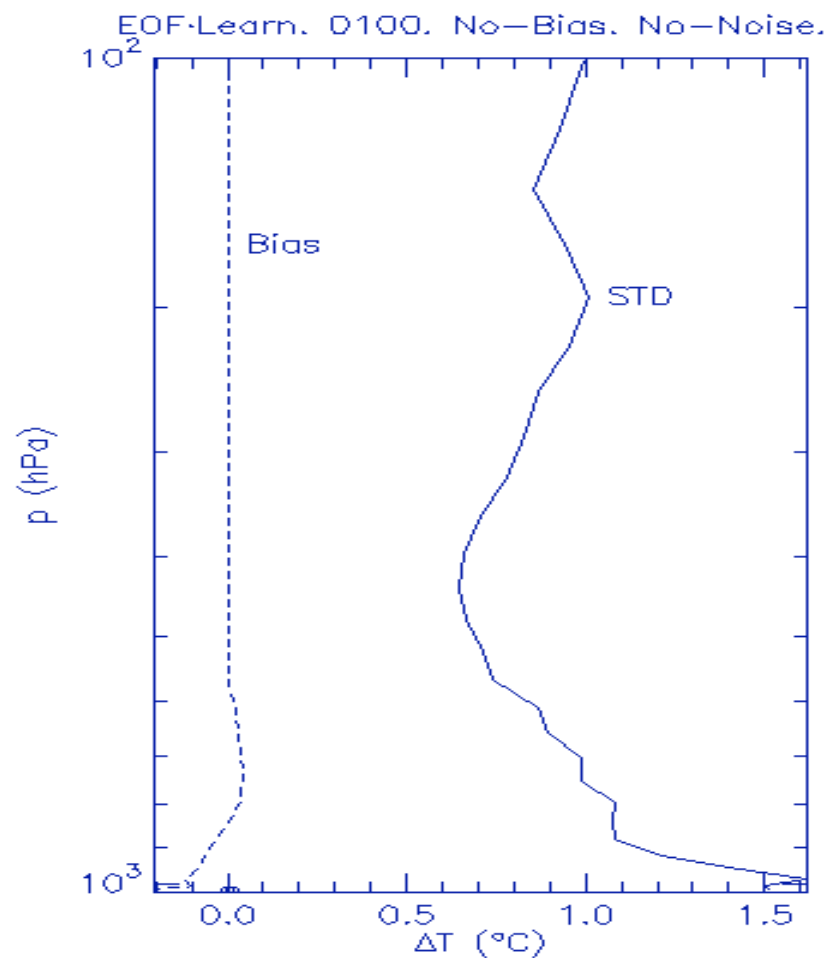
CLEAR SKY EOF retrieval

The training of the EOF linear retrieval consisted of:

- Training the retrieval with:
 - **Atmospheric profiles:** modified “Sampled database of 60-level atmospheric profiles from the ECMWF analyses” (F. Chevallier)
 - **Radiative Transfer Model (RTM):** RTTOV8-beta
 - **EOF scores:** Obtained from brightness temperatures
 - **Linear fit of EOF scores with atmospheric profiles:** with and without noise added to the spectra

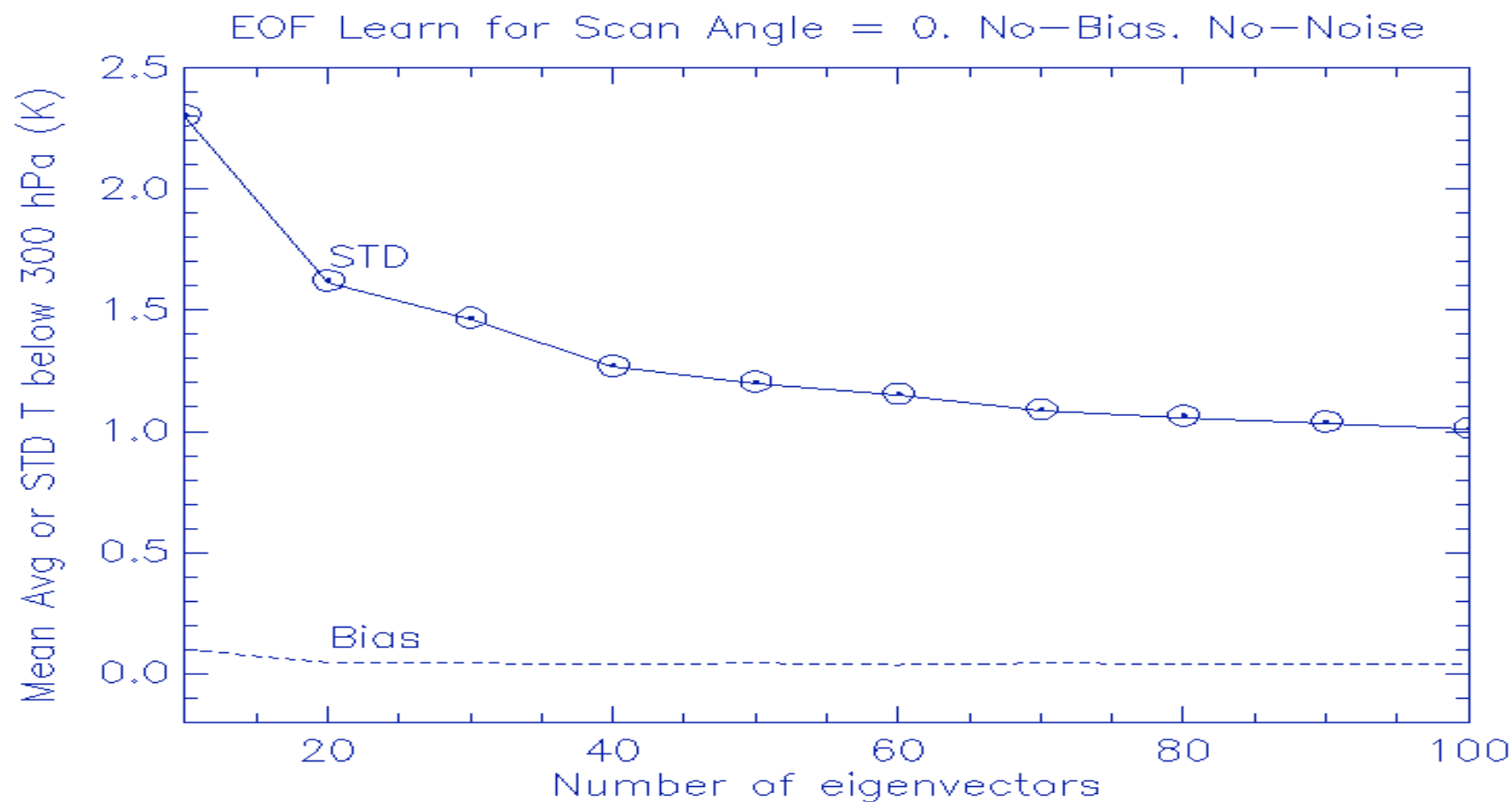
CLEAR SKY EOF retrieval

First tested with the synthetic training cases:



CLEAR SKY EOF retrieval

First tested with the synthetic training cases:



CLEAR SKY EOF retrieval

Retrievals:

- Retrieving for clear-sky over ocean AIRS soundings during one randomly chosen day (6/10/2003)
- The ECMWF analyses were taken as the “truth” for comparison purposes.

CLEAR SKY EOF retrieval

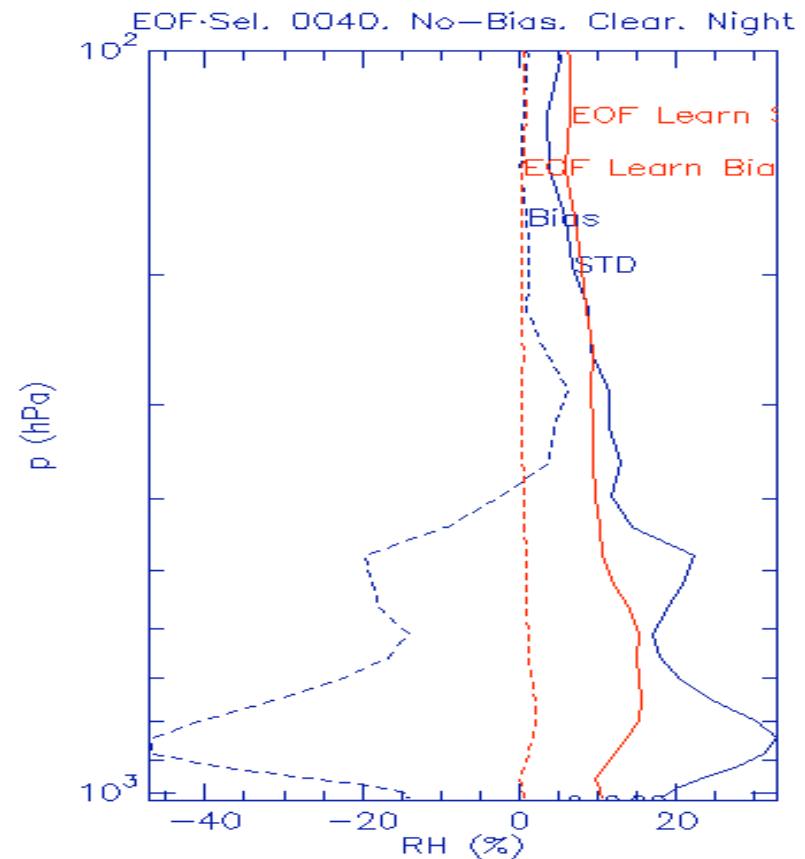
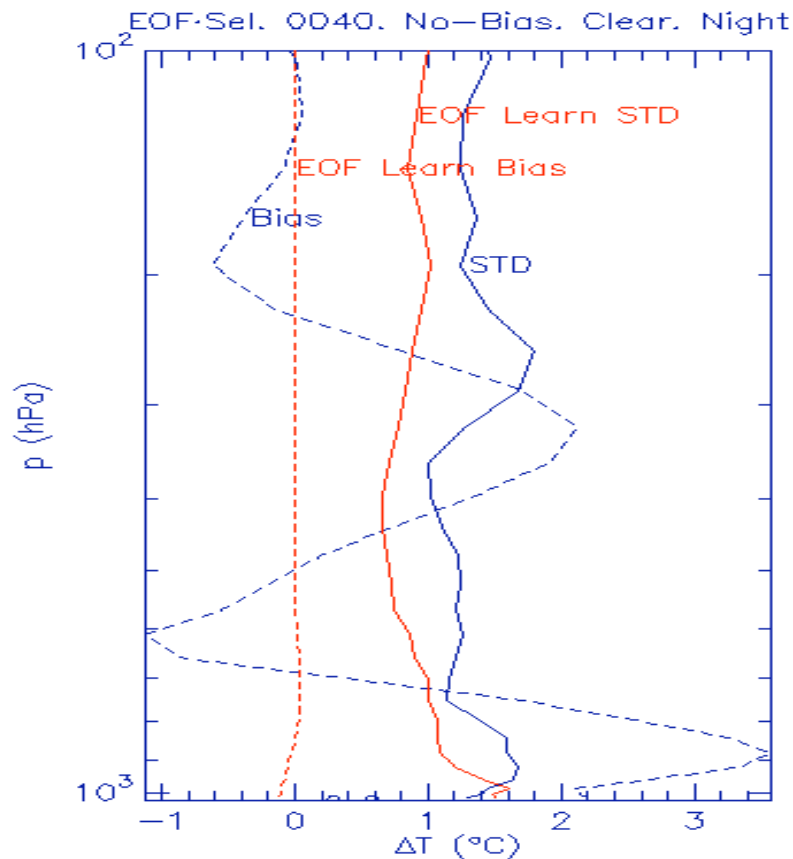
Problems found:

- Channels with excessive noise had to be removed from the whole EOF retrieval chain.

CLEAR SKY EOF retrieval

Results Nighttime with no noise in training and no bias correction:

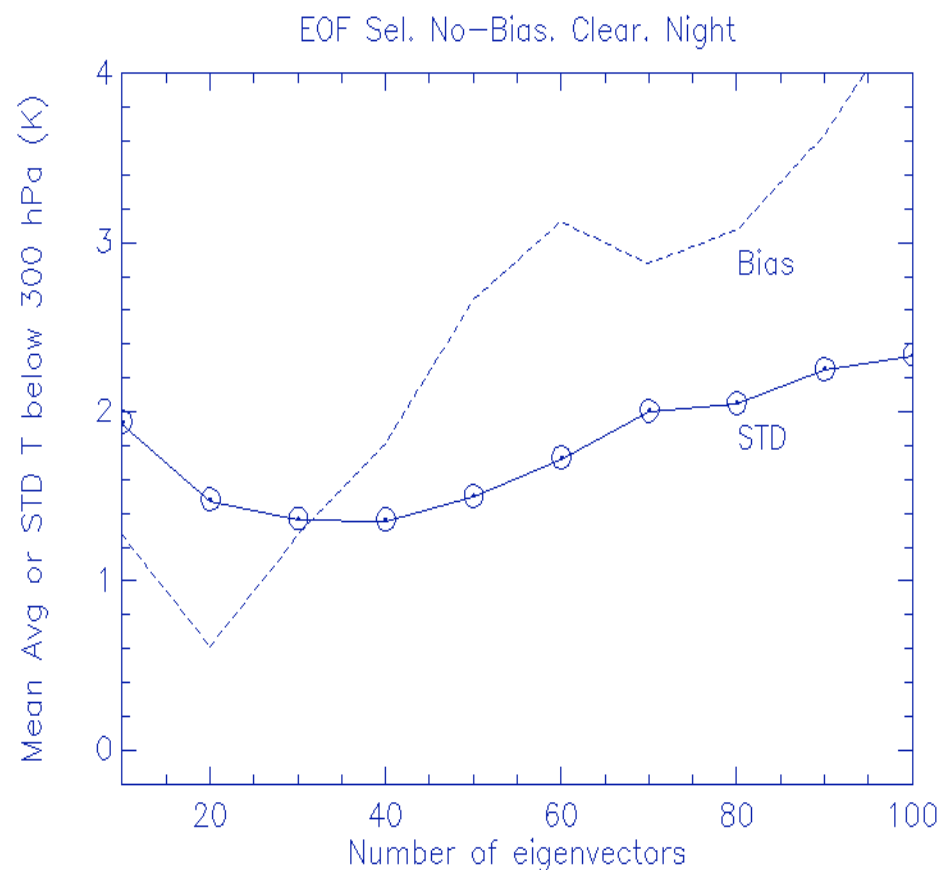
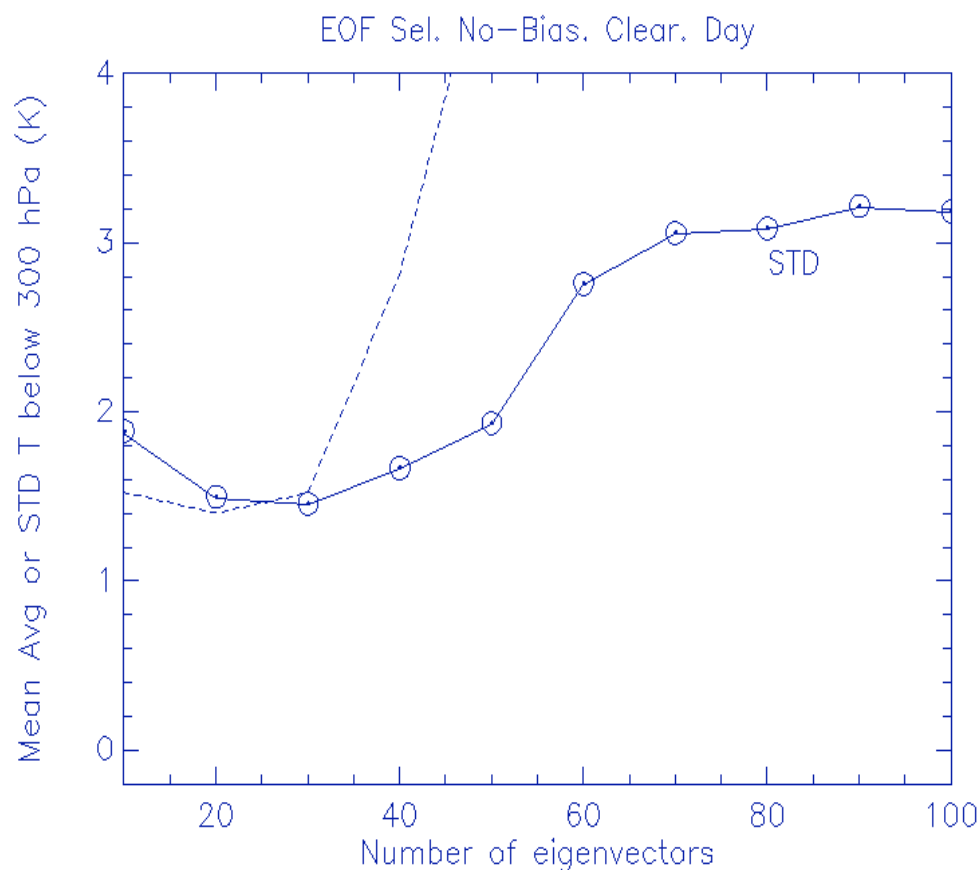
- A high bias was found between the observed and retrieved spectra
- T STD of 1-2K, RH STD of 10-20%



CLEAR SKY EOF retrieval

Results with no noise in training and no bias correction:

- Different numbers of eigenvectors were tried.



Analytical BIAS and STD corrections

Training model: $Y'_{M,ij} = F_M(X'_{M,ik}),$ Atmosphere: $Y'_{A,ij} = F_A(X'_{A,ik}),$

Resultant
BIAS

$$\overline{X'_{R,k}} - \overline{X'_{A,k}} = \sum_{j=1}^p \beta_{kj} \sum_{k=1}^m e_{kj} (\overline{Y'_{A,k}} - \overline{Y'_{M,k}}) + \overline{X'_{M,k}} - \overline{X'_{A,k}},$$

$k = 1 \dots q$ (Atmospheric state number)

Optimal
STD

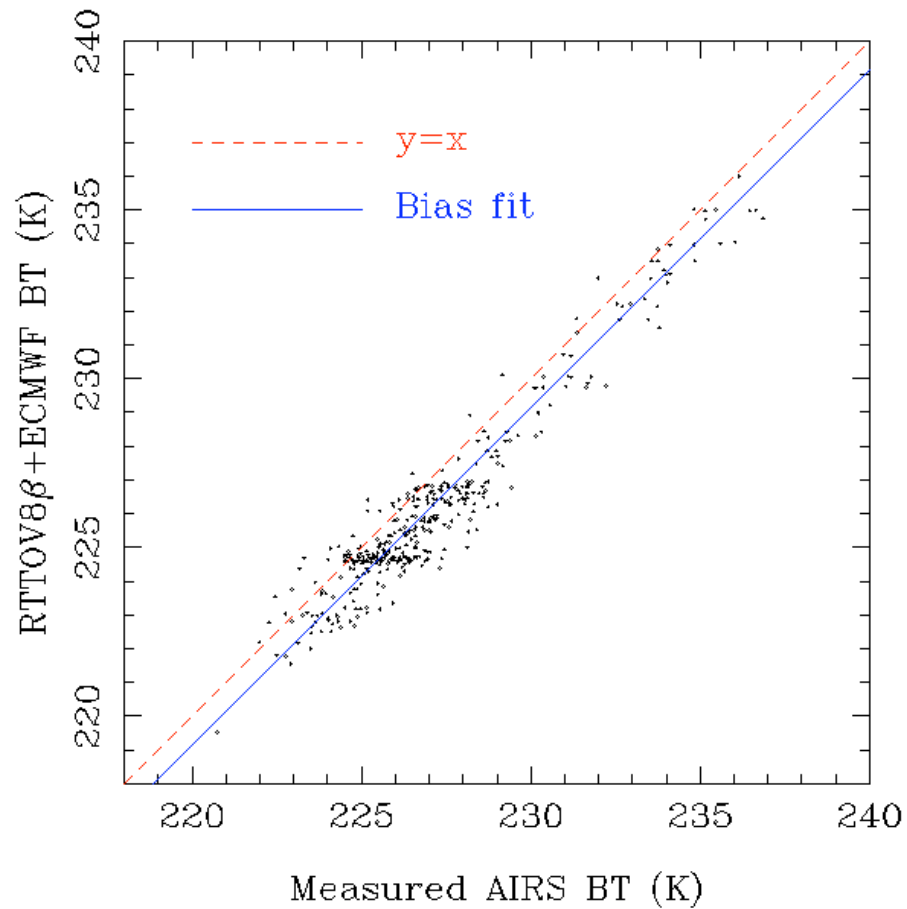
$$\sum_{i=1}^{n_M} X_{M,ij} Y_{M,ik} = \sum_{i=1}^{n_A} X_{A,ij} Y_{A,ik},$$

$$\sum_{i=1}^{n_M} Y_{M,ij} Y_{M,ik} = \sum_{i=1}^{n_A} Y_{A,ij} Y_{A,ik}$$

BIAS corrections

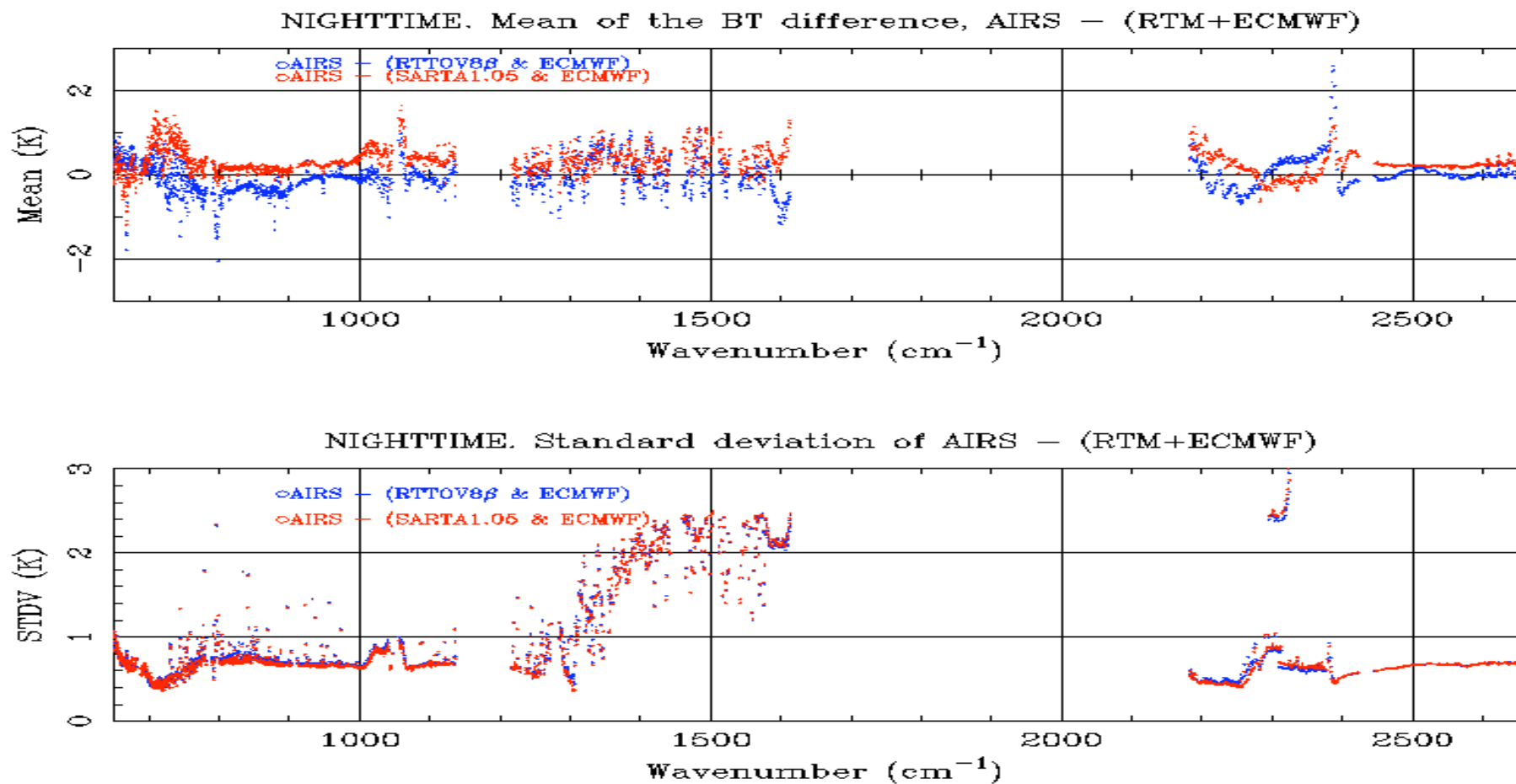
Evidence for a bias

Channel 0023, 654.902 cm^{-1}



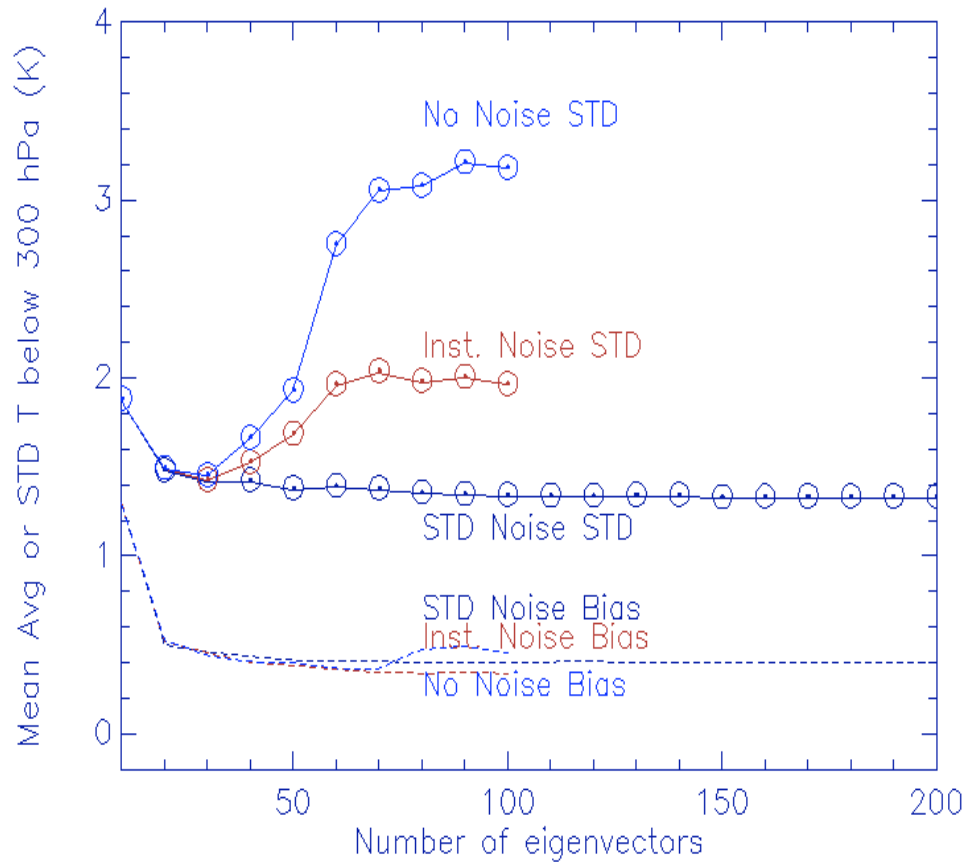
BIAS corrections

Bias and STD: Nighttime

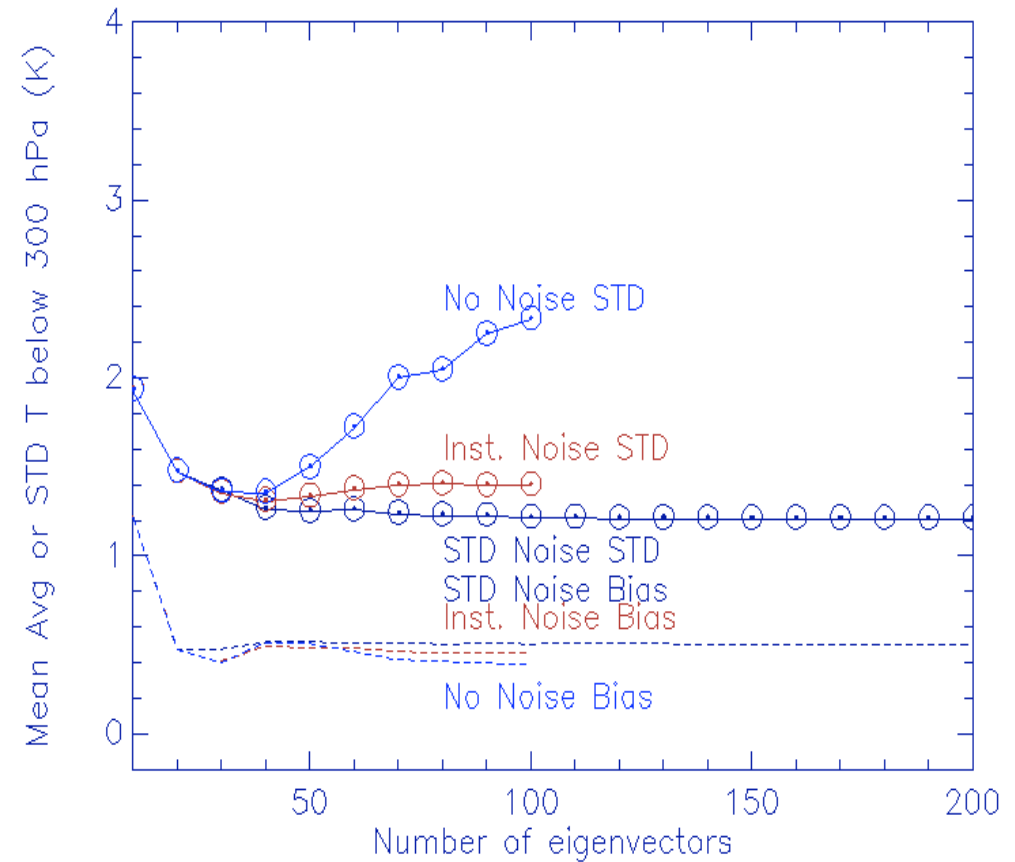


CLEAR SKY BIAS and STD corrected EOF retrieval

EOF Sel. STD-Noise+Bias. Clear. Day



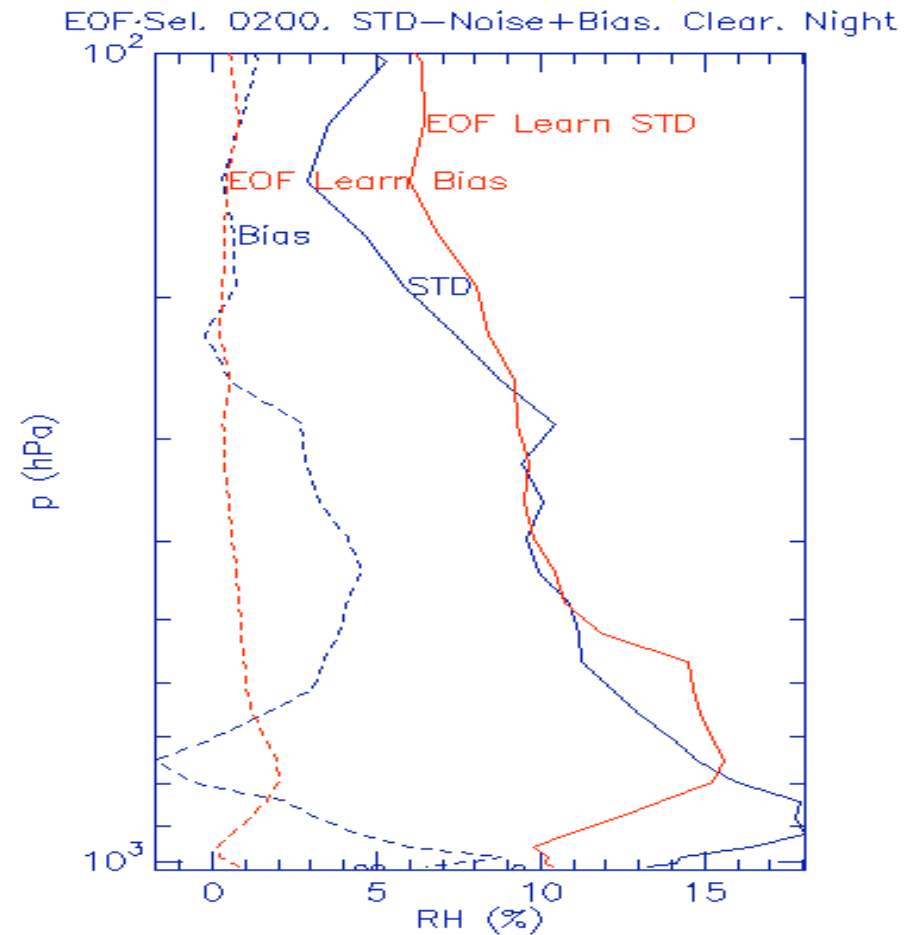
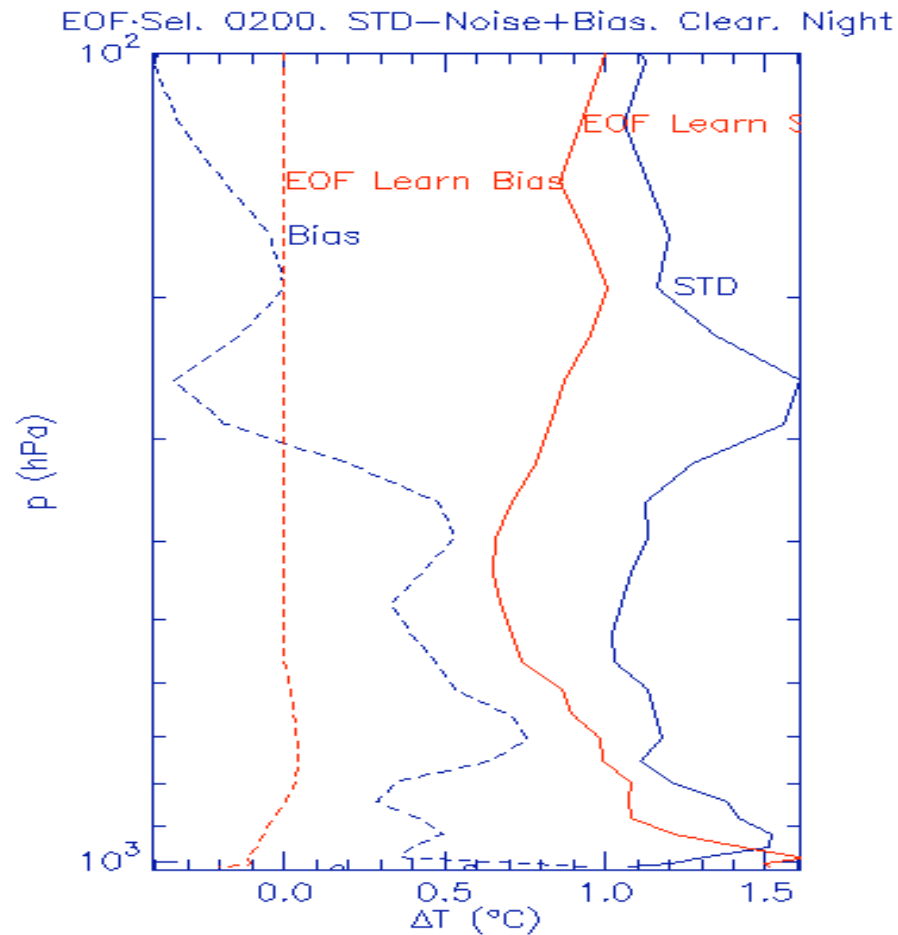
EOF Sel. STD-Noise+Bias. Clear. Night



CLEAR SKY BIAS and STD corrected EOF retrieval

Results Nighttime:

- Tstdv of 1 - 1.5 K, RHstdv of 10-20%



CLEAR SKY Variational retrieval

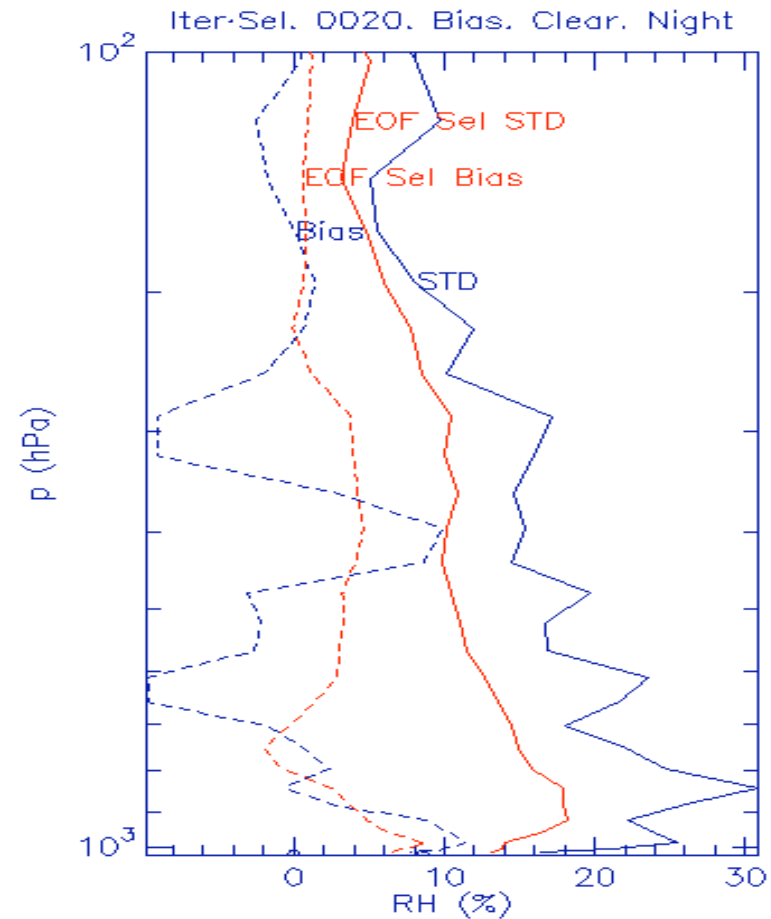
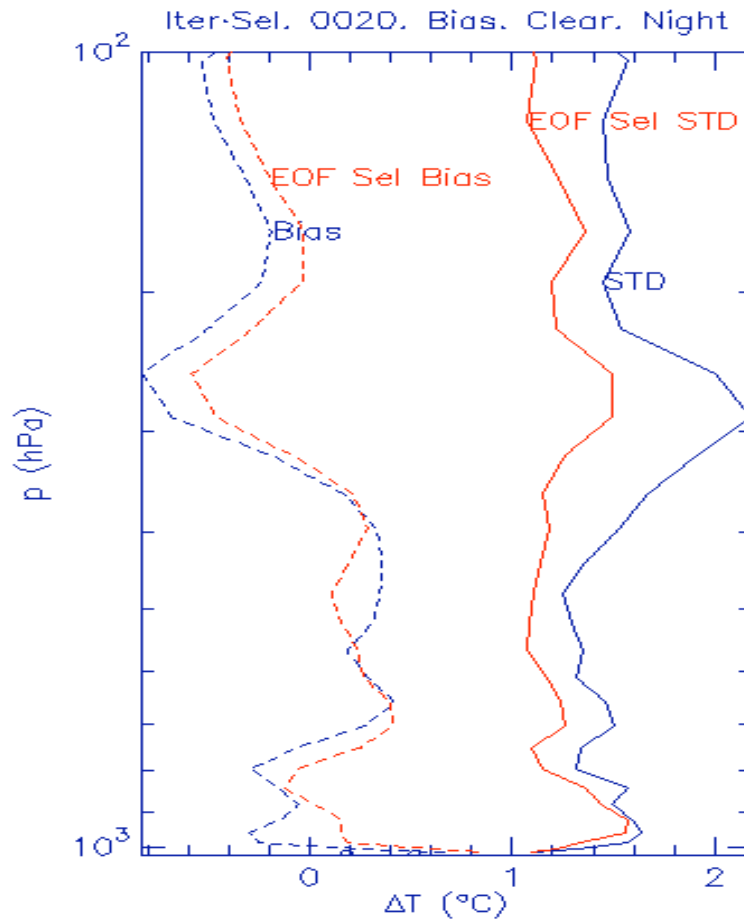
The variational non-linear retrieval consisted of:

- Use of the Levenberg-Marquardt method.
- RTTOV8-beta was used as the RTM.
- Initialisation with the EOF retrievals.
- Surface emissivity, trace gases, O3 and surface pressure were not retrieved.
- Two step retrieval: first W V retrieval with W V band and second T,W V profiles and SST retrieval with “all” channels.
- All channels used except: flagged as bad and STD greater than 2K in the (RTTOV+ECMWF) - AIRS comparison
- Constraints used: forbid super-adiabatic lapse rates and super-saturation.

CLEAR SKY BIAS corrected Variational retrieval

Results Nighttime:

- Very slightly worse than EOF



CLEAR SKY retrieval Conclusions

- The EOF method provides good retrievals and it is not computationally expensive.
- EOF: First order corrections: Bias corrections
- EOF: Second order corrections: STD corrections
- When compared with more accurate atmospheric data, some Variational retrievals **could** be better than EOF retrievals, since they show **more detail**.
- Atmospheric profile retrievals provide a good way to test errors of the whole processing chain on which infrared retrieved soundings are based.

CLOUDY SKY over OCEAN retrievals

CLOUDY SKY Variational retrieval

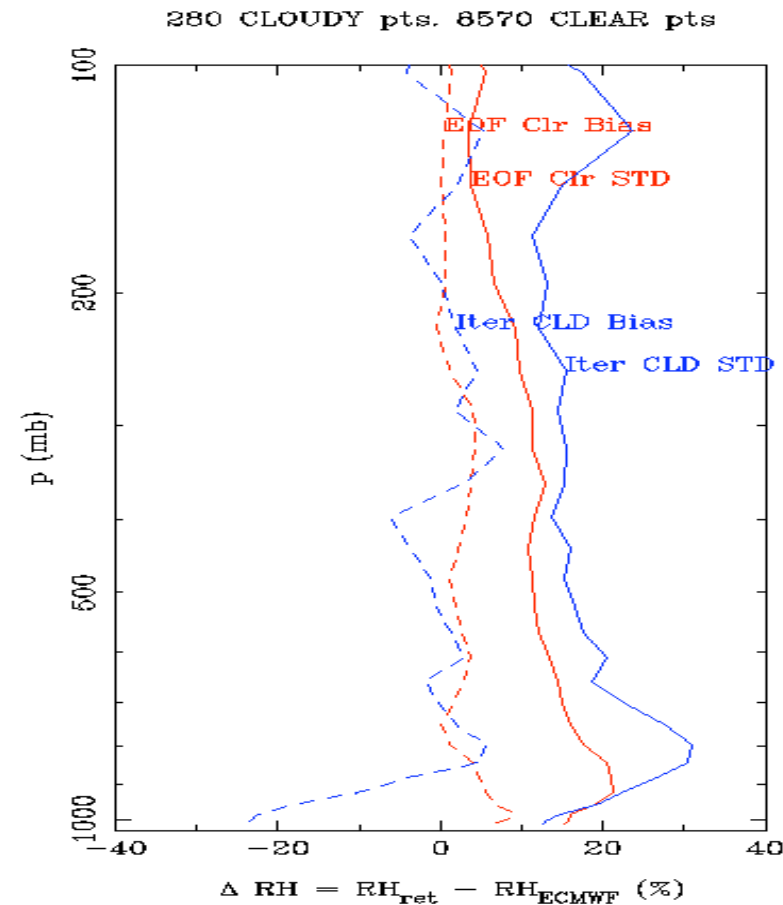
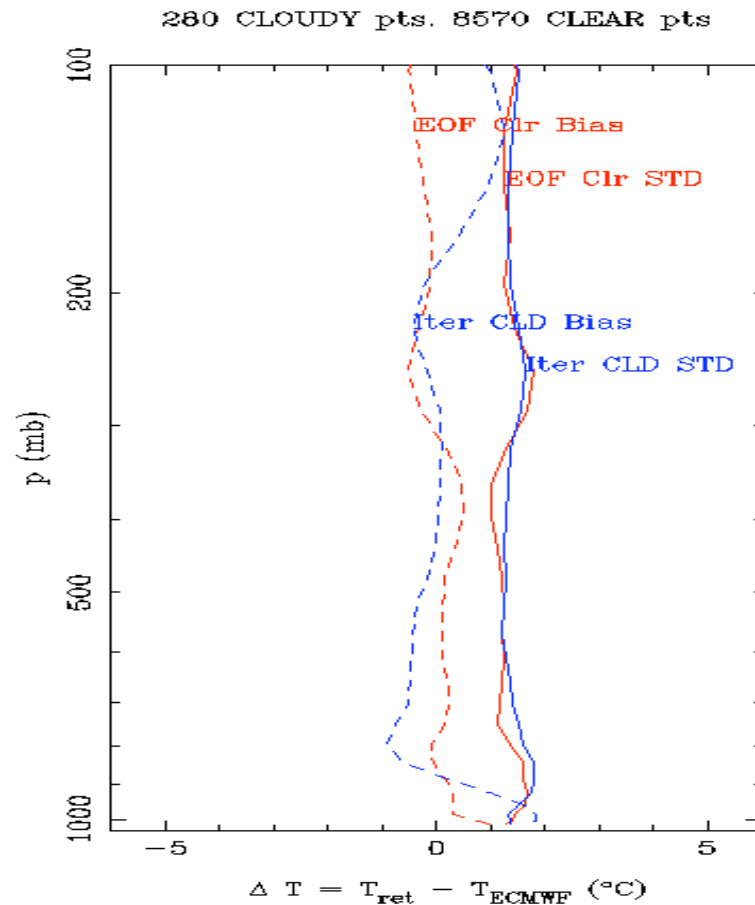
The variational non-linear retrieval consisted of the same method as the clear sky retrieval plus:

- RTTOV8-beta black cloud model used
- Added constraints: no SST retrieved and surface air temperature forced to SST.
- Cloud top set to the inversion height or where super-saturation occurs.
- Only retrievals with smaller residuals and cloud fraction below 70% used in the statistics

CLOUDY SKY BIAS corrected Variational retrieval

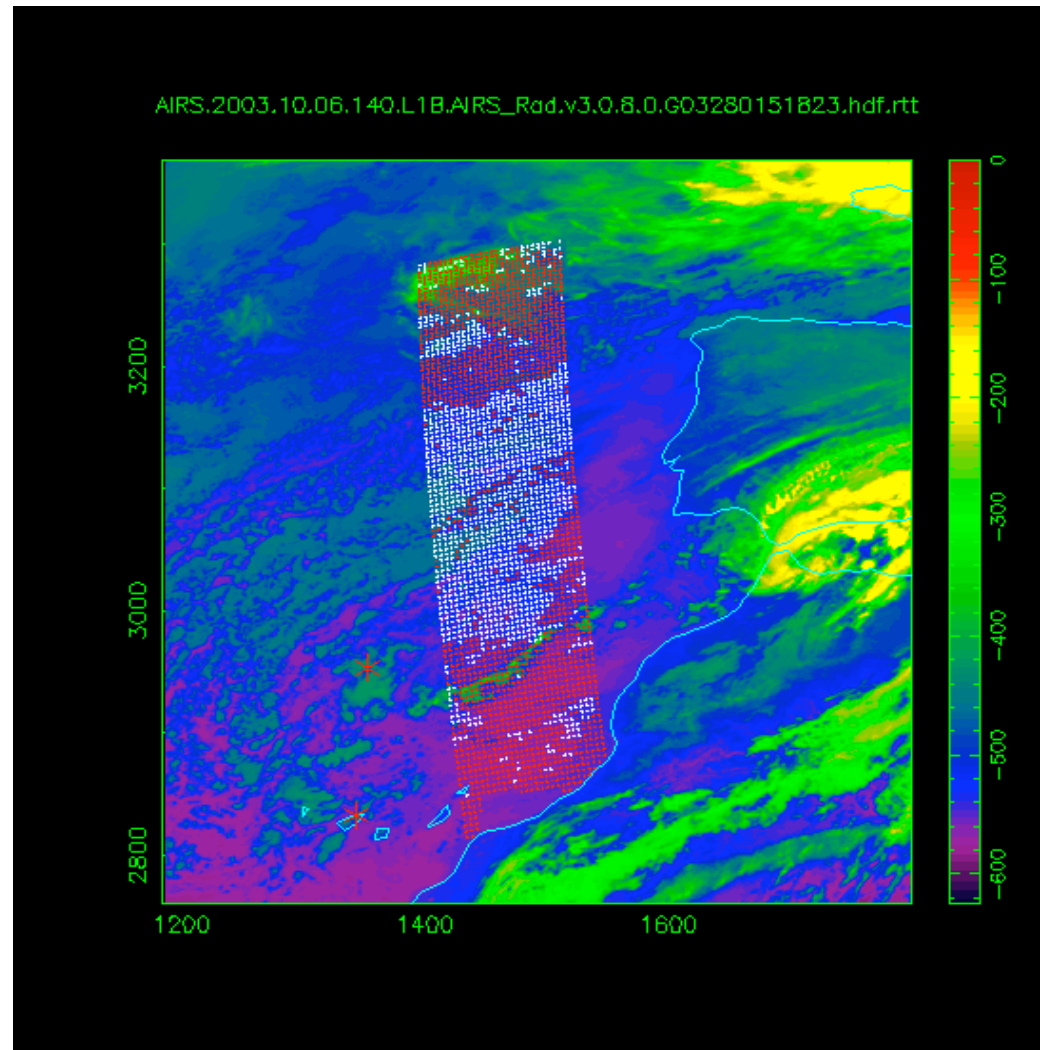
Results Nighttime:

- STD similar to EOF clear nighttime. Big biases.



CLOUDY SKY BIAS corrected Variational retrieval (DAY)

GENERAL VIEW

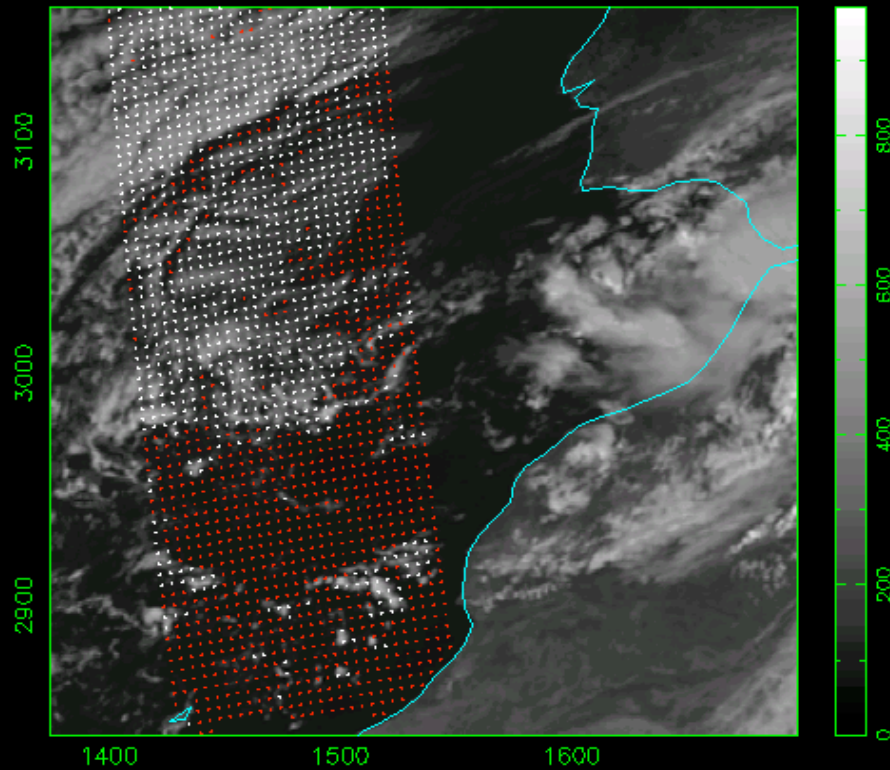


CLOUDY SKY BIAS corrected Variational retrieval (DAY)

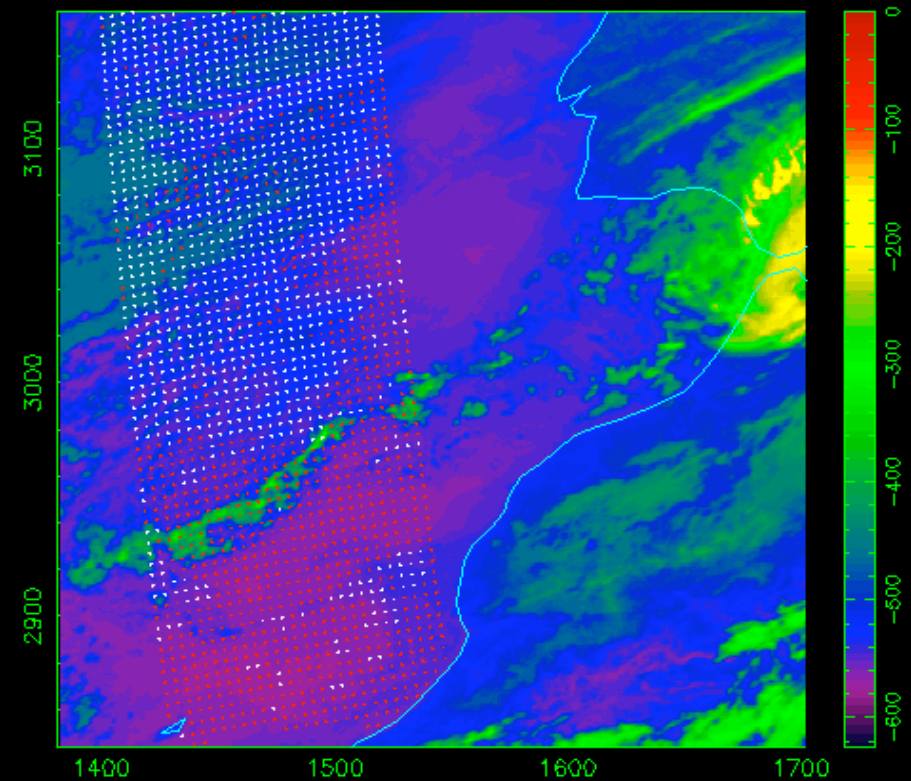
VIS

IR

AIRS.2003.10.06.140.L1B.AIRS_Rad.v3.0.8.0.G03280151823.hdf.rtt



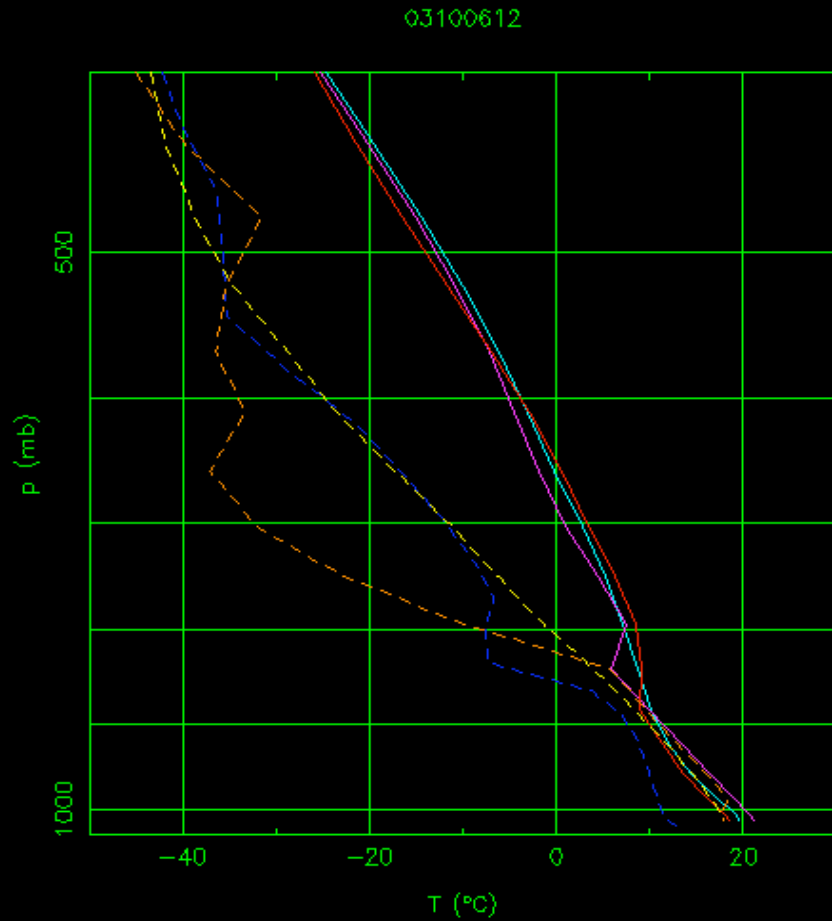
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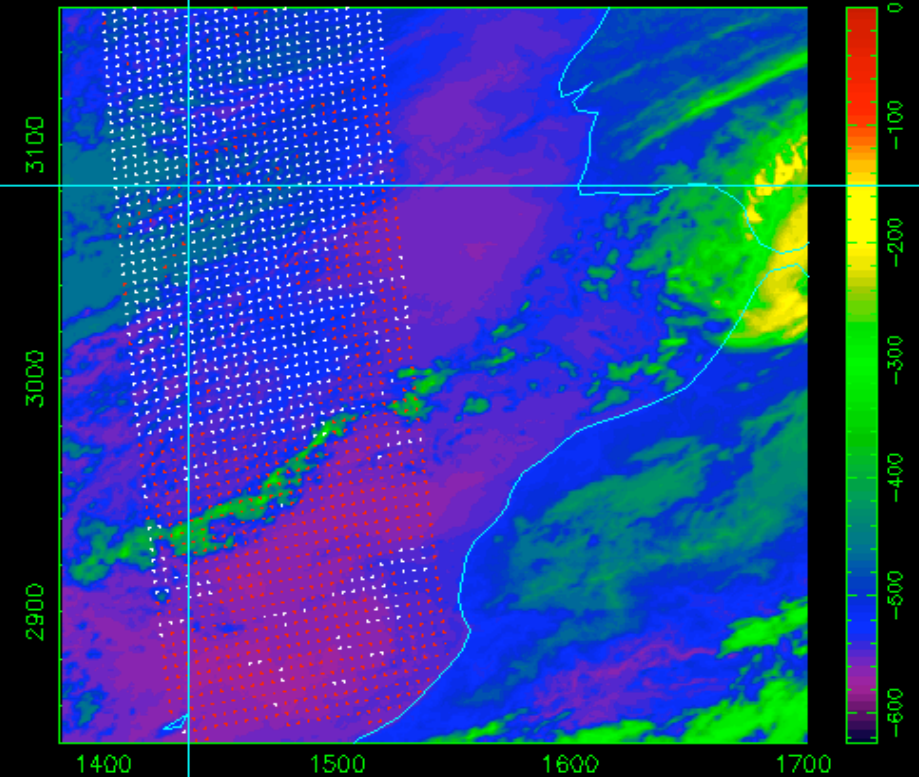
CLOUDY SKY BIAS corrected Variational retrieval (DAY)

"HOLE"

IR



AIRS.2003.10.06.140.L1B.AIRS_Rad.v3.0.8.0.G03280151823.hdf.rtt



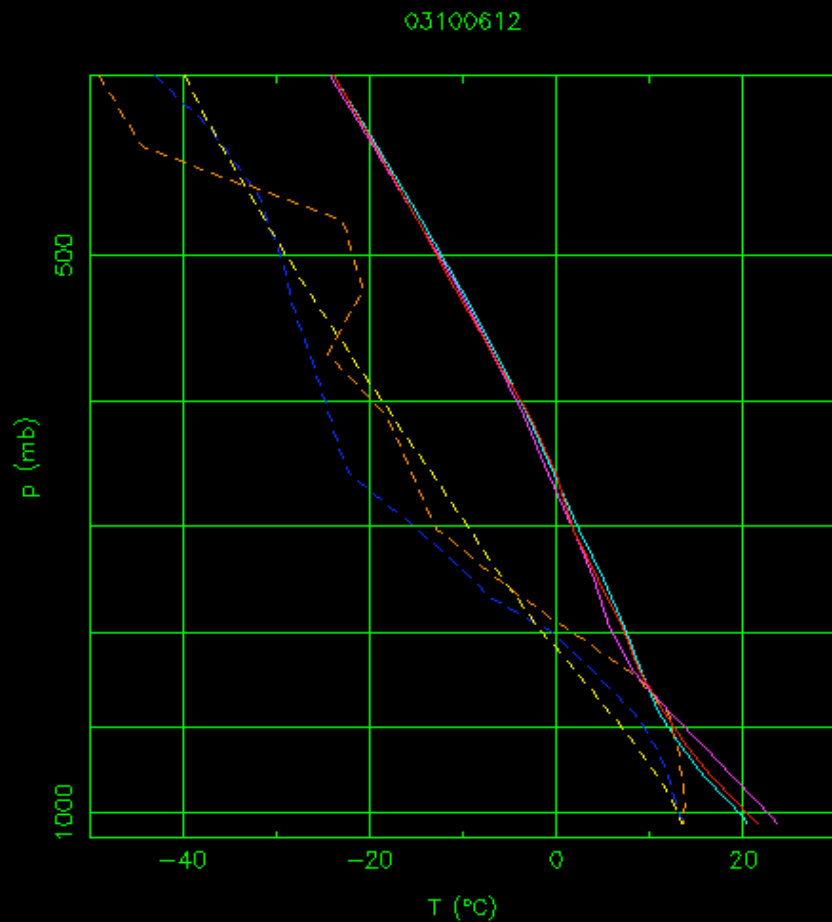
Solid: T. Dashed: T_dew. Red/Blue: ECMWF. Cyan/Yellow: EOF. Magenta/Orange: VAR



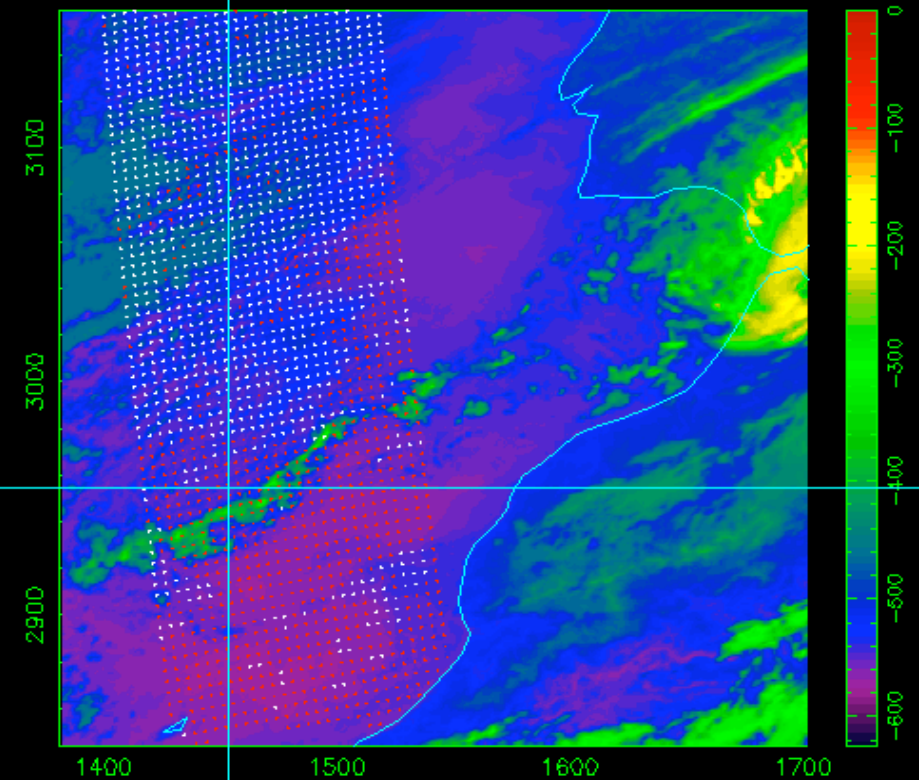
CLOUDY SKY BIAS corrected Variational retrieval (DAY)

"POST FRONT"

IR



AIRS.2003.10.05.140.L1B.AIRS_Rad.v3.0.8.0.G03280151823.hdf.rtt



Solid: T. Dashed: T_dew. Red/Blue: ECMWF. Cyan/Yellow: EOF. Magenta/Orange: VAR

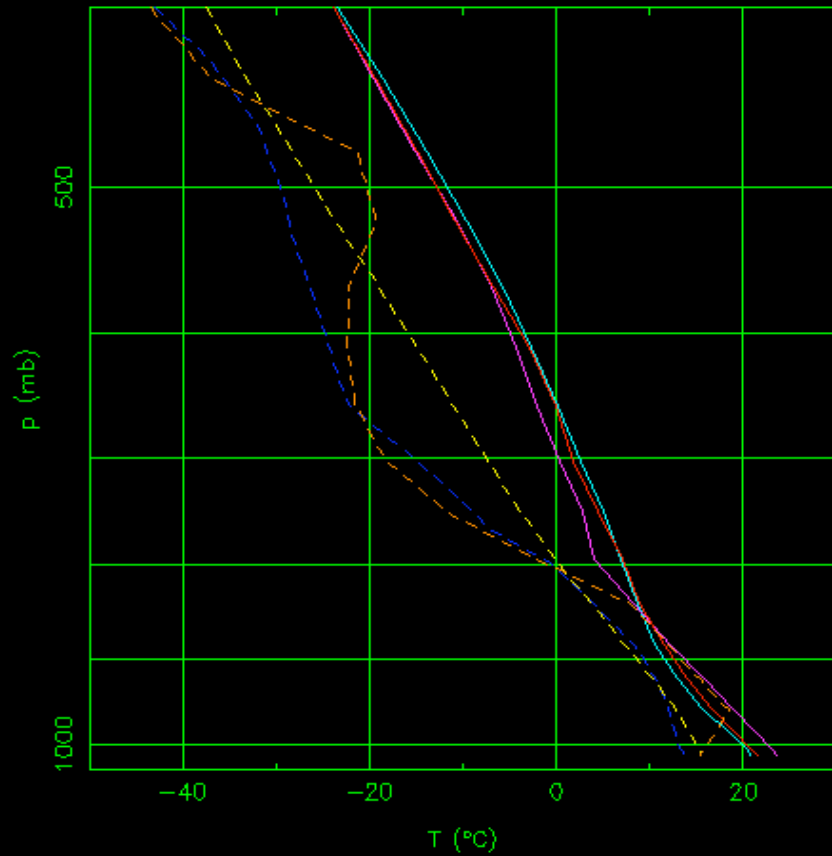


CLOUDY SKY BIAS corrected Variational retrieval (DAY)

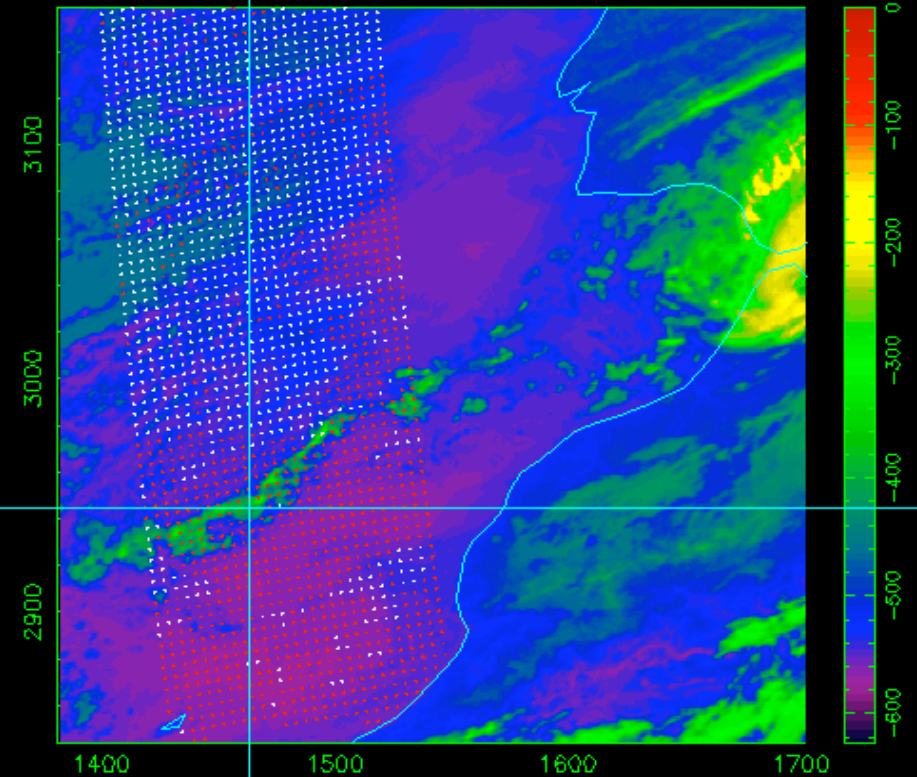
"FRONT"

IR

03100612



AIRS.2003.10.06.140.L1B.AIRS_Rad.v3.0.8.0.G03280151823.hdf.rtt



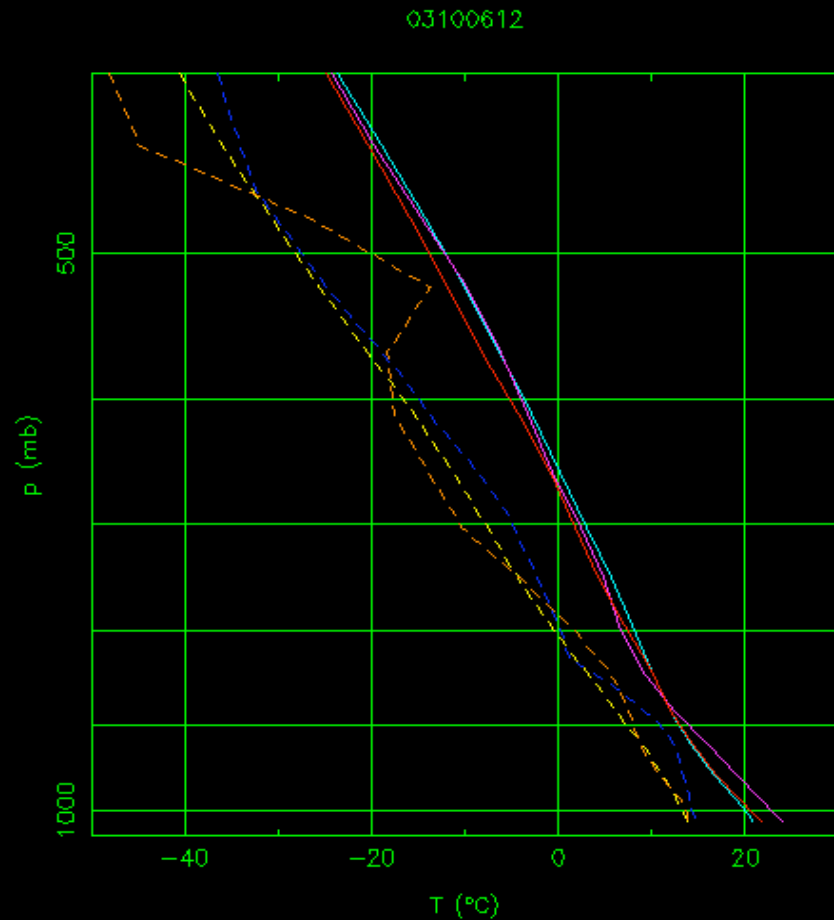
Solid: T. Dashed: T_dew. Red/Blue: ECMWF. Cyan/Yellow: EOF. Magenta/Orange: VAR



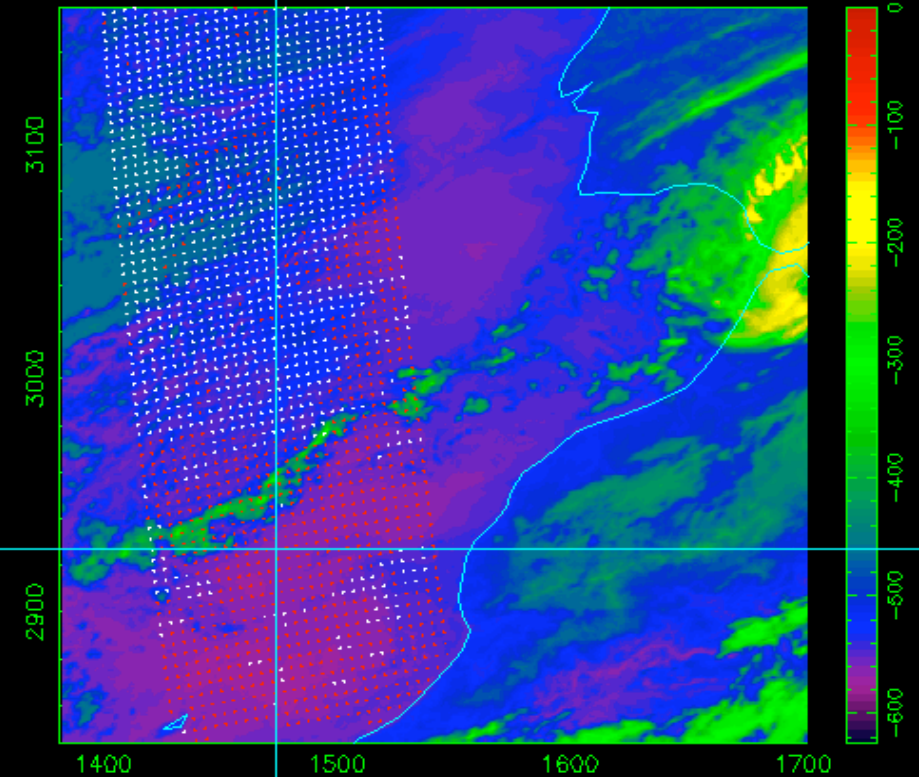
CLOUDY SKY BIAS corrected Variational retrieval (DAY)

"PRE FRONT"

IR



AIRS.2003.10.06.140.L1B.AIRS_Rad.v3.0.8.0.G03280151823.hdf.rtt



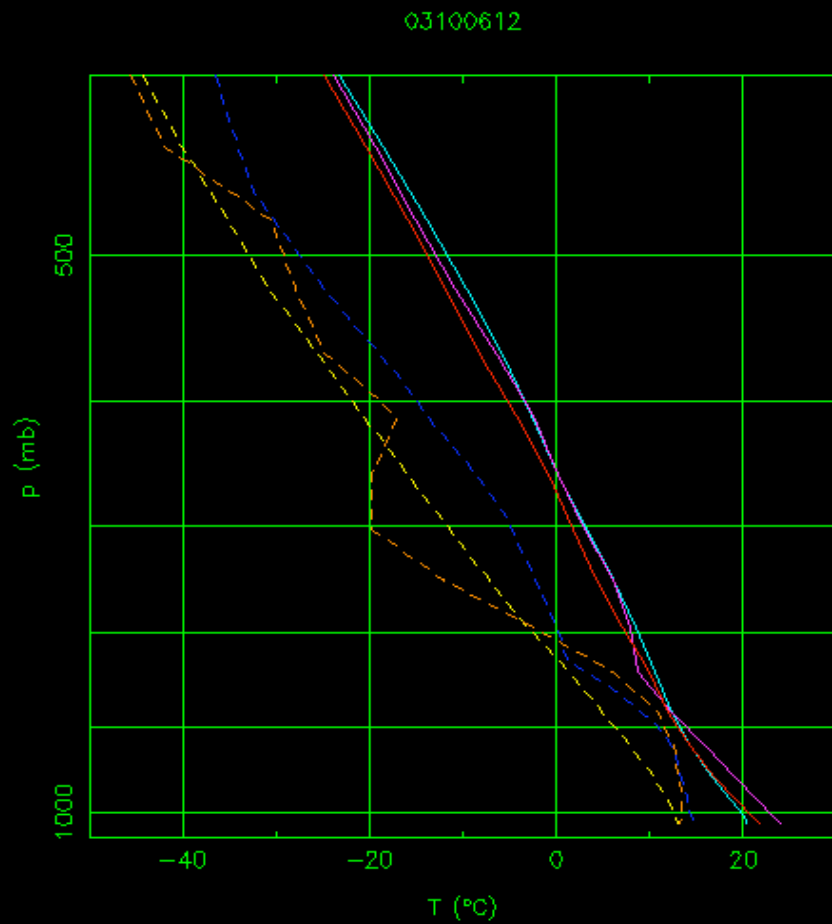
Solid: T. Dashed: T_dew. Red/Blue: ECMWF. Cyan/Yellow: EOF. Magenta/Orange: VAR



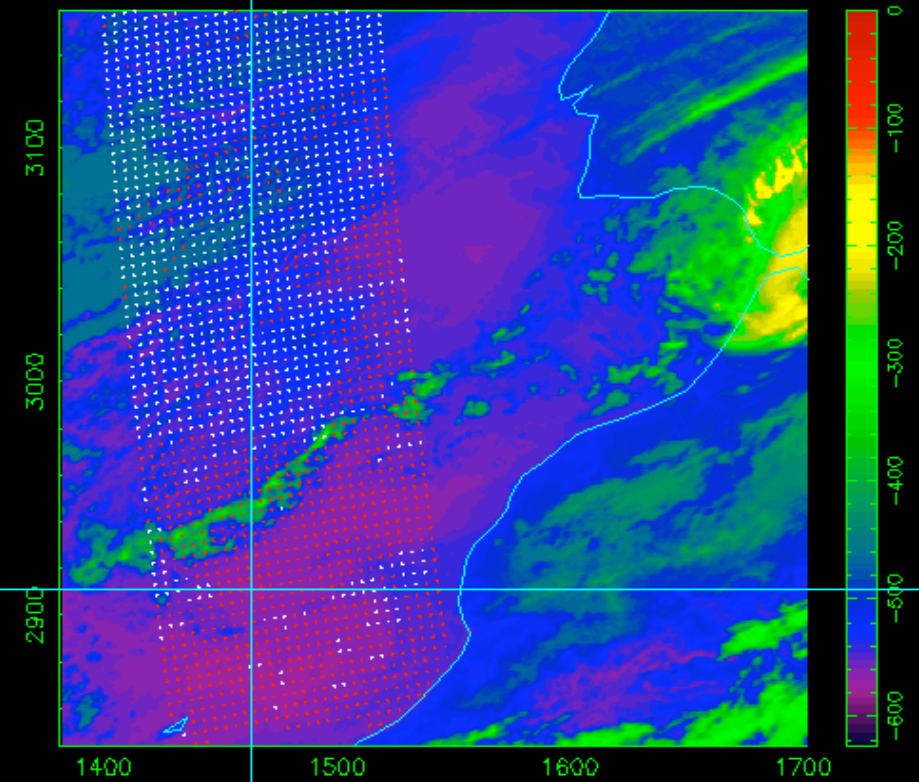
CLOUDY SKY BIAS corrected Variational retrieval (DAY)

"PRE FRONT 2"

IR



AIRS.2003.10.06.140.L1B.AIRS_Rad.v3.0.8.0.G03280151823.hdf.rtt



Solid: T. Dashed: T_{dew}. Red/Blue: ECMWF. Cyan/Yellow: EOF. Magenta/Orange: VAR

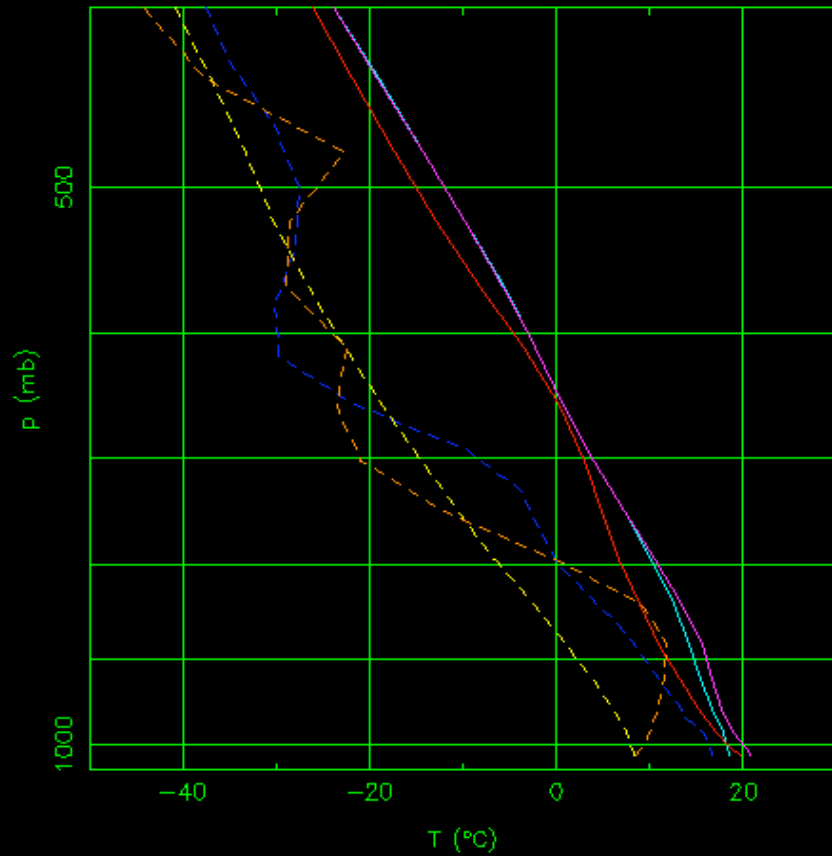


CLOUDY SKY BIAS corrected Variational retrieval (DAY)

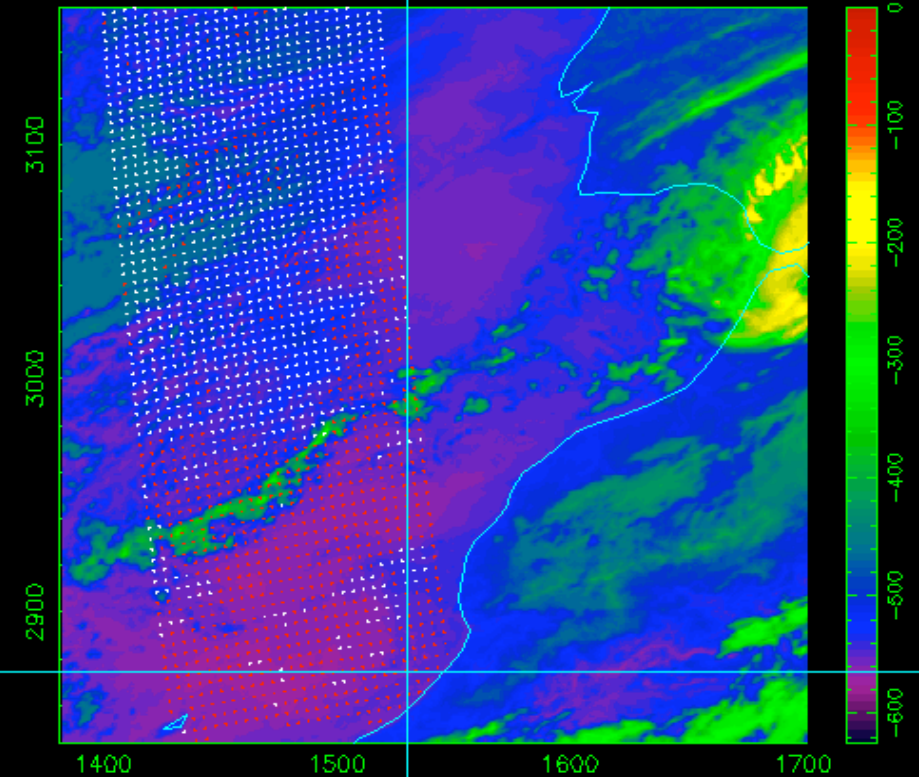
“CLEAR”

IR

03100612



AIRS.2003.10.06.140.L1B.AIRS_Rad.v3.0.8.0.G03280151823.hdf.rtt



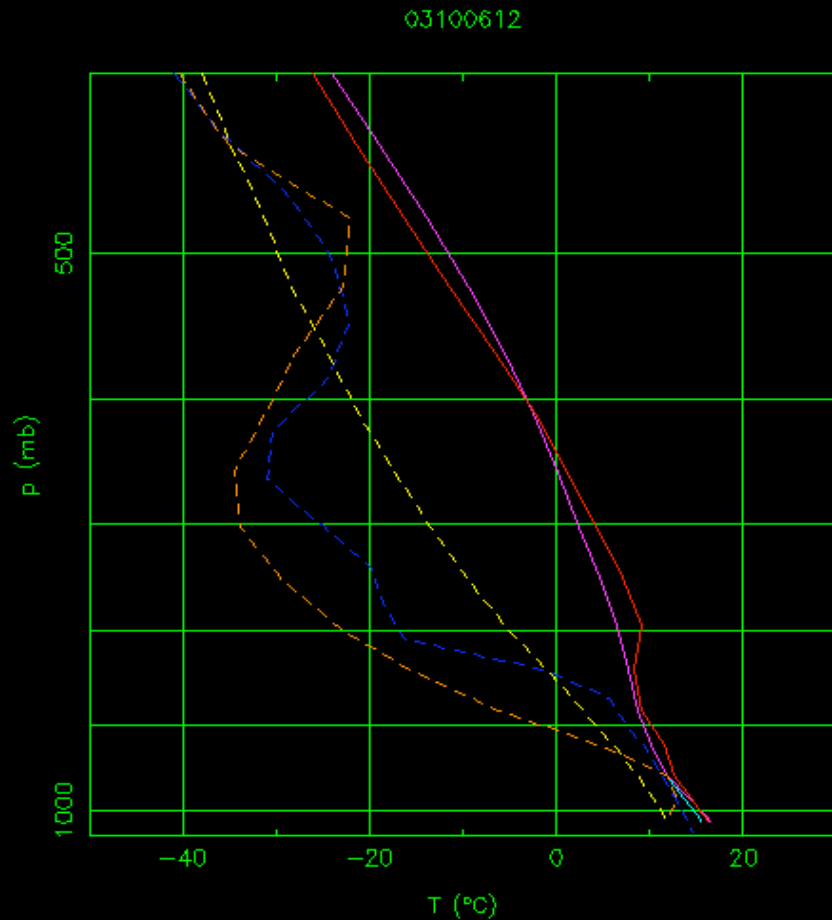
Solid: T. Dashed: T_{dew}. Red/Blue: ECMWF. Cyan/Yellow: EOF. Magenta/Orange: VAR



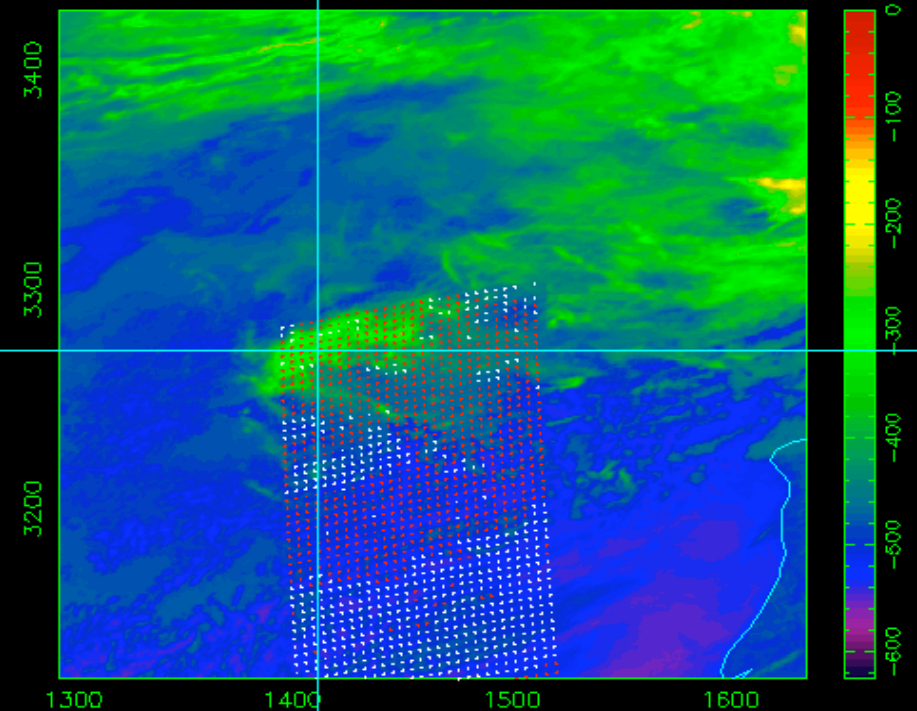
CLOUDY SKY BIAS corrected Variational retrieval (DAY)

"CIRRUS"

IR



AIRS.2003.10.06.140.L1B.AIRS_Rad.v3.0.8.0.G03280151823.hdf.rtt



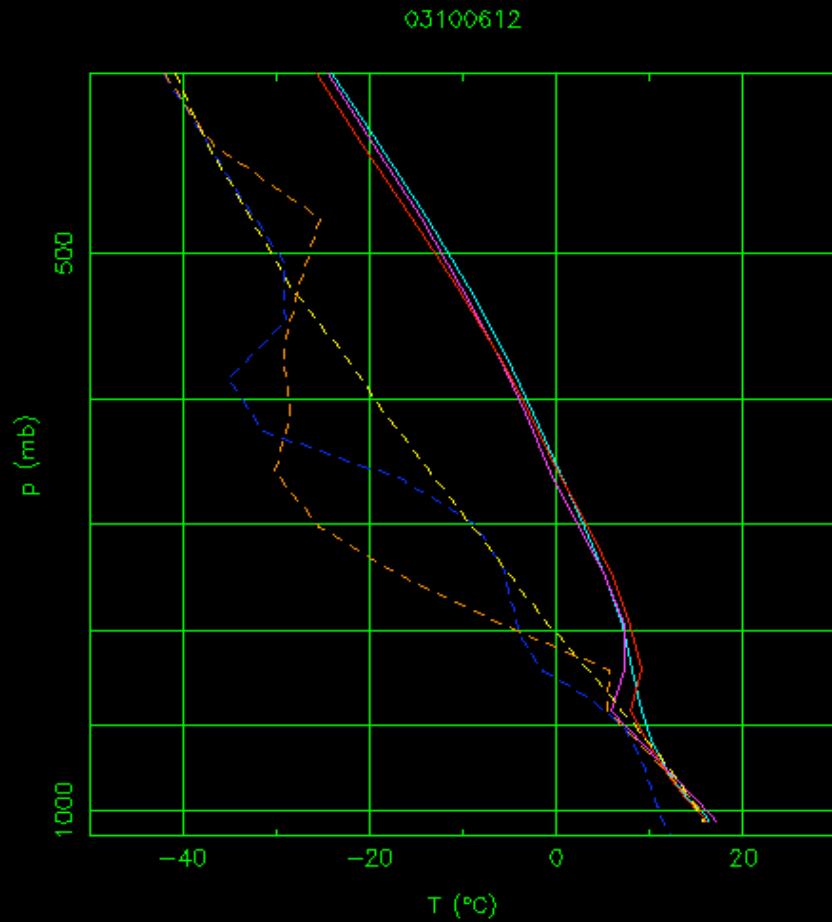
Solid: T. Dashed: T_dew. Red/Blue: ECMWF. Cyan/Yellow: EOF. Magenta/Orange: VAR



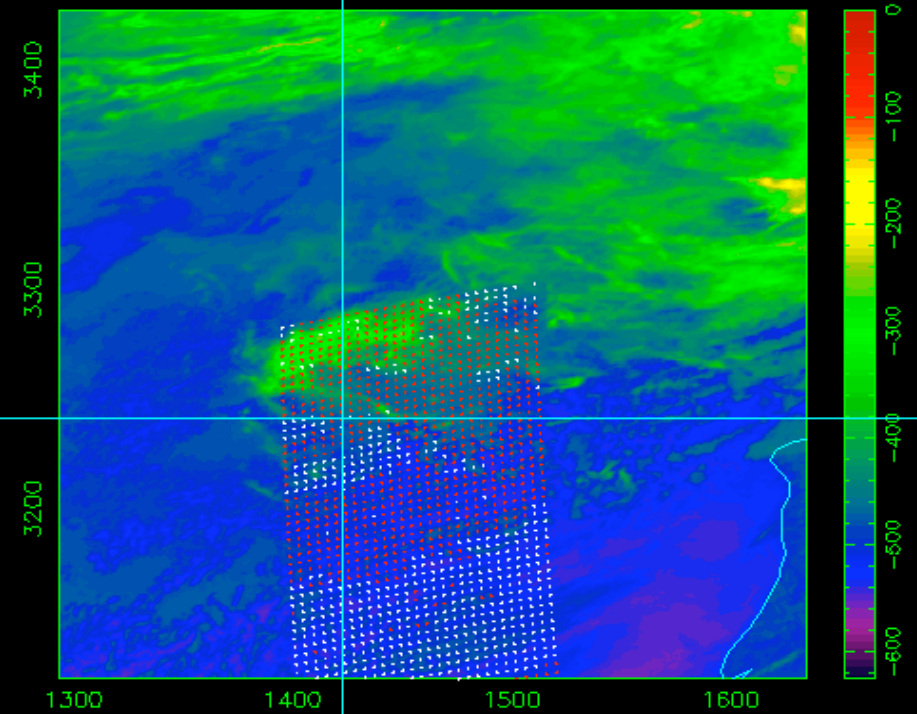
CLOUDY SKY BIAS corrected Variational retrieval (DAY)

"CIRRUS2"

IR



AIRS.2003.10.06.140.L1B_AIRS_Rad.v3.0.8.0.G03280151823.hdf.rtt



Solid: T. Dashed: T_{dew}. Red/Blue: ECMWF. Cyan/Yellow: EOF. Magenta/Orange: VAR



CLOUDY SKY retrieval Conclusions

- Variational cloudy retrieval provide good results with such simple assumptions.
- Biases still too high.
- STD comparable to EOF clear sky daytime retrievals
- Too many constraints below the inversion layer make the retrieval slow.

Appendix A: Clear Sky used

Clear sky ~ $-1 \text{ K} < T(3.9 \text{ um}) - T(10.8\text{um}) < 3 \text{ K}$

$T(10.8\text{um}) > 276 \text{ K}$

$T(11\text{um}) > \text{SST} - 2.2 \text{ K}$

$T(4.0\text{um}) - T(11.0\text{um}) > 12 \text{ K}$

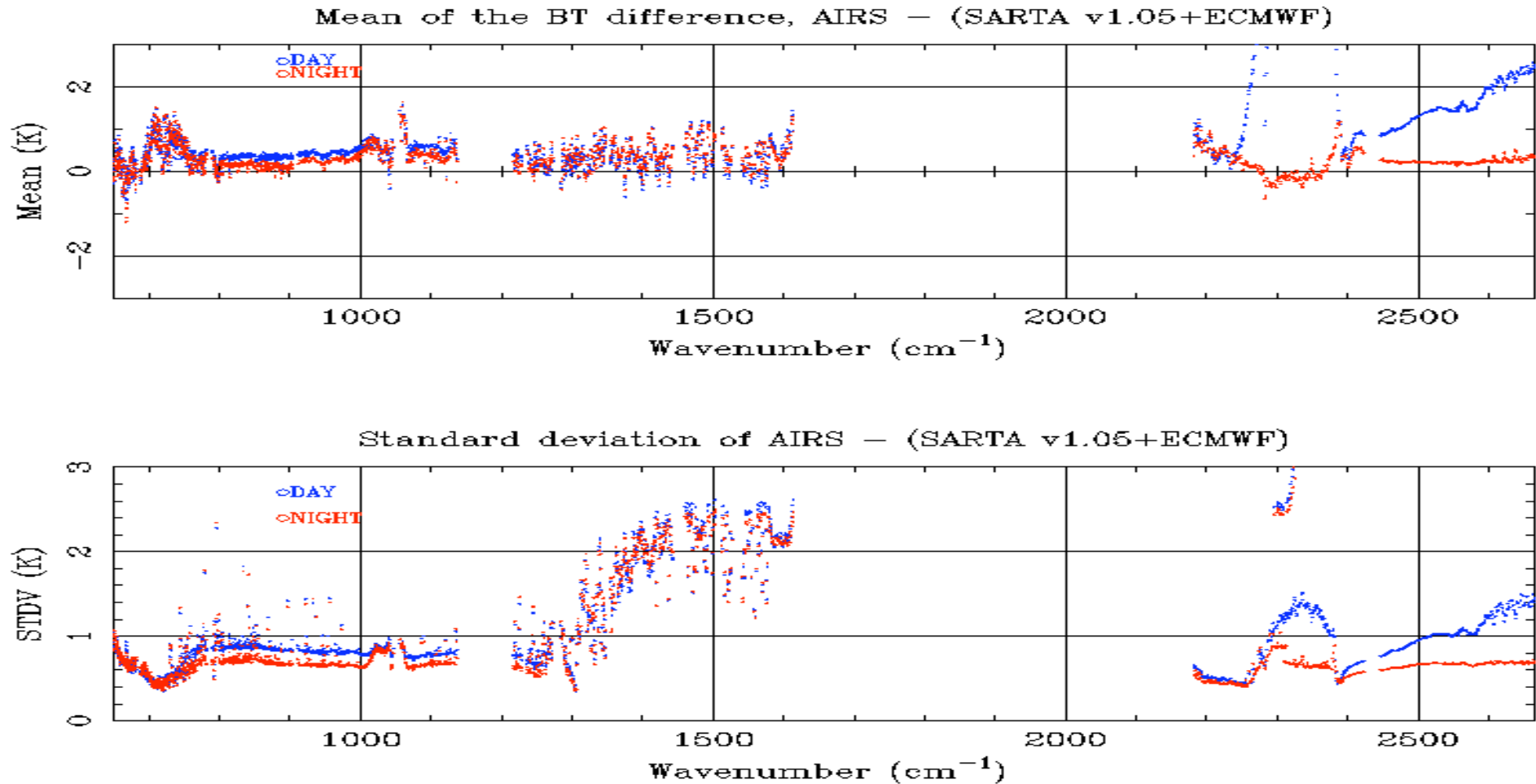
$T(9.3\text{um}) - T(11.0\text{um}) < 0 \text{ K}$

$T(11.0\text{um}) - T(12.0\text{um}) < 1 \text{ K}$

$T(11.0\text{um}) - T(13.6\text{um}) > 18 \text{ K}$

Appendix B: BIAS corrections

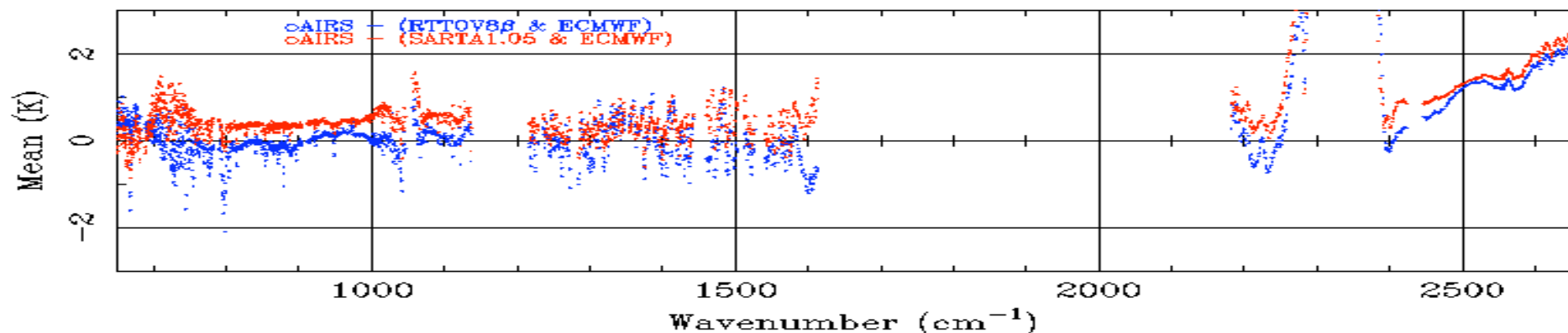
Mean Bias and STD: SARTA Day & Night



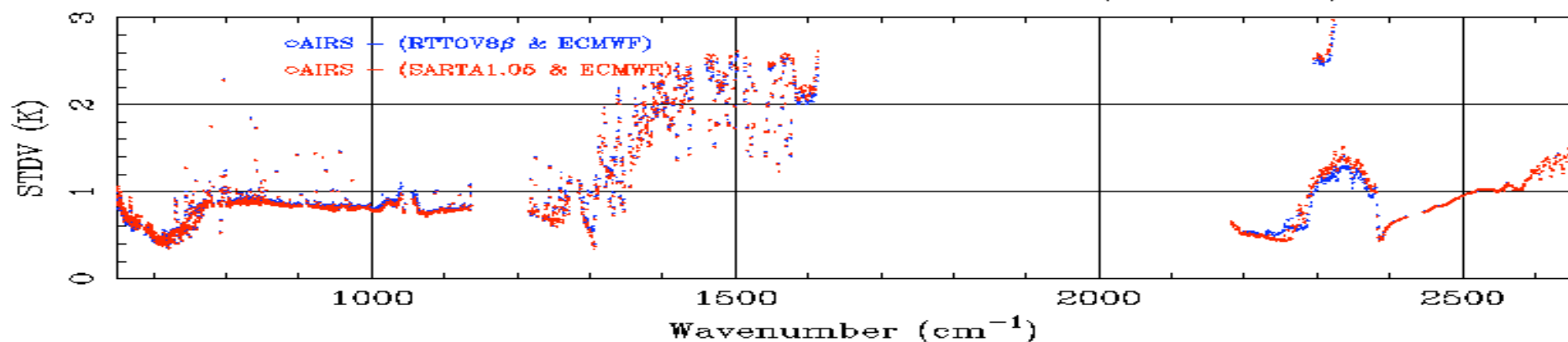
Appendix C: BIAS corrections

Mean bias and STD: Daytime

DAYTIME. Mean of the BT difference, AIRS - (RTM+ECMWF)



DAYTIME. Standard deviation of AIRS - (RTM+ECMWF)



Appendix D: BIAS corrections

Mean Bias and STD: RTTOV Day & Night

